

J. W. KNOWLTON
METHOD AND MOLD FOR MAKING BORON
CARBIDE ARTICLES
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FIG. 1

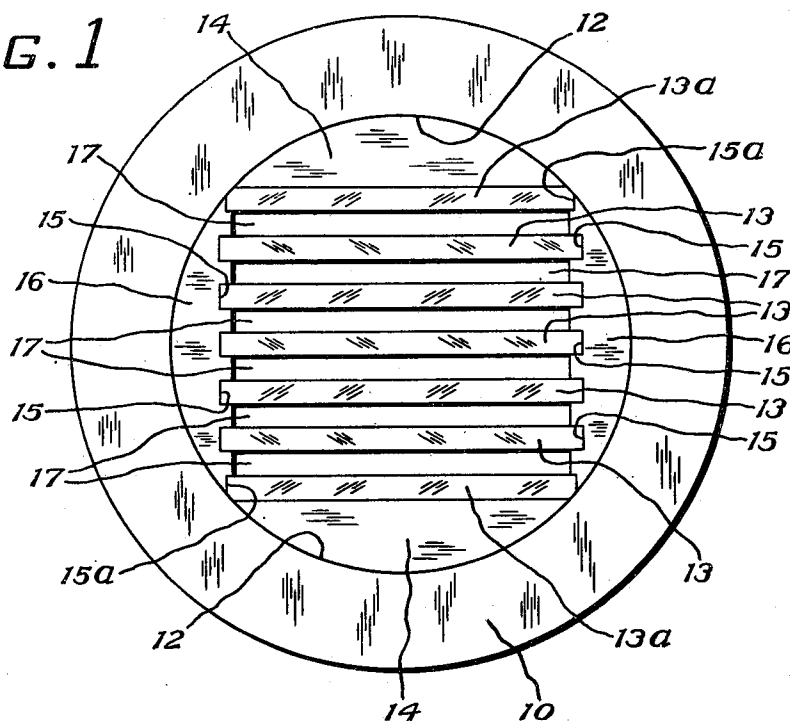


FIG. 2

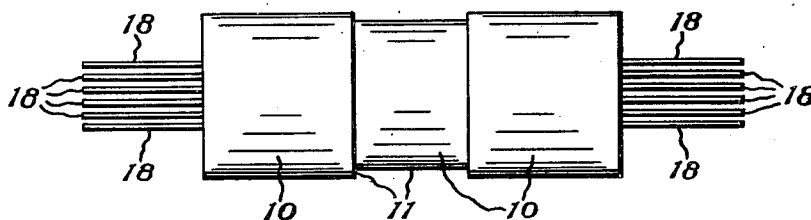


FIG. 3

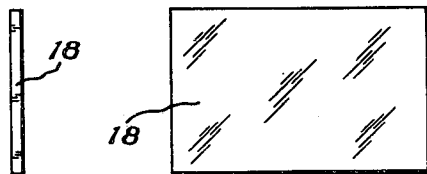


FIG. 4

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UNITED STATES PATENT OFFICE

2,473,476

METHOD AND MOLD FOR MAKING BORON CARBIDE ARTICLES

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2 Claims. (Cl. 25—118)

1

The invention relates to the molding of refractory material, under heat and pressure, and with regard to its more specific features, to the molding of boron carbide articles from powders thereof.

One object of the invention is to provide a method of molding for the production of long flat pieces. Another object of the invention is to increase the versatility of a molding machine such as, for example, constructed along the lines of U. S. Patent No. 2,125,588 to Raymond R. Ridgway. Another object of the invention is to reduce the number of rejected pieces which have been molded under heat and pressure in apparatus of the above patent or in like apparatus. Another object is to facilitate the production of molded pieces of boron carbide or other refractory material which are long and wide but thin. Another object of the invention is to provide a satisfactory graphite mold for the manufacture of flat plates of boron carbide and similar shapes of that or other refractory material. Another object of the invention is to provide a method and apparatus for the manufacture of a plate for an abrasive throwing wheel out of hard material such as boron carbide. Other objects will be in part obvious or in part pointed out hereinafter.

The invention accordingly consists in the features of construction, combinations of elements, arrangement of parts, and in the several steps and relation and order of each of said steps to one or more of the others thereof, all as will be illustratively described herein, and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings illustrating a specific mold constructed in accordance with the invention and which may be used to carry out the process of the invention.

Figure 1 is an end view of a mold;

Figure 2 is a side view of the mold of Figure 1, shown on a reduced scale, after it has been loaded;

Figure 3 is an end view of a mold plunger on a different scale;

Figure 4 is a side view of the mold plunger of Figure 3.

Abrasive throwing wheels are described in the following U. S. Patents: Nos. 2,204,633; 2,204,634; 2,204,635; 2,301,508; 2,314,069. Abrasive material or steel shot is propelled centrifugally by such wheels in order to clean castings or perform any other rough abrading action. Such wheels have hard plates or other shapes to resist the abrasive action of the material propelled. Nevertheless such plates or other shapes wear very rapidly. Furthermore even when the plates or shapes have been made of hardened steel or iron they have frequently been broken by the impact of the steel shot.

2

Resistance to wear and resistance to shock are incompatible qualities, and a satisfactory material for abrasive throwing wheel plates had not been found. I have made the surprising discovery that boron carbide, B_4C , is a satisfactory and superior material for the wear resistance element of abrasive throwing wheels despite its lack of resistance to mechanical shock. Boron carbide has great resistance to wear, being the hardest material known next to the diamond.

An element of the character indicated may be in the form of a rectangular parallelepiped, thin in reference to its length and width provided it shall be of generous size. The above listed patents are illustrative only and abrasive throwing wheels exist which can use a long thin flat plate of rectangular parallelepipedal shape. However heretofore no one had ever made a flat plate of boron carbide of a length more than seven times the thickness. Attempts to do so resulted in making fractured plates for reasons which were not apparent. I have discovered a method of making plates up to $6\frac{3}{8}$ " long by $2\frac{5}{8}$ " wide by $\frac{1}{8}$ " thick which are highly efficient for the purpose indicated.

The mold illustrated in the drawings and many others which can be made in accordance with this invention is adapted for use in a pressure molding apparatus such as is described in the patent to Ridgway No. 2,125,588. Accordingly, for a full understanding of the present invention, reference should be made to that patent which is fully descriptive of high temperature molding of boron carbide. However a mold made as shown in that patent is not adapted for the manufacture of thin plates.

Referring now to Figures 1 and 2, the mold 10 is adapted for the manufacture of a boron carbide plate $6\frac{3}{8}$ " x $2\frac{5}{8}$ " x $\frac{1}{8}$ ". The mold 10, which is made of graphite, has a main diameter of $5\frac{1}{2}$ inches interrupted by a centrally located groove 11 three and one half inches long and $\frac{1}{4}$ inch deep. The mold 10 is thirteen inches long overall. It has an axial bore 12 which is $3\frac{1}{8}$ inches in diameter. In this bore 12 are five graphite separator plates 13 each one of which is a perfect rectangular parallelepiped thirteen inches long, $\frac{1}{8}$ inch thick and $2\frac{1}{8}$ inches wide. Two more graphite separator plates 13a are of the same shape and size excepting that a pair of corners are bevelled as shown; and the width is $2\frac{3}{8}$ ".

The separator plates 13a are just inside of cylindrical segments 14 of graphite which fit the bore 12. These plates 13a and the plates 13 fit in grooves 15a and 15 of graphite cylindrical segments 16 which likewise fit the bore 12. The segments 14 and 16 are thirteen inches long.

The mold has six mold cavities 17 each of which is thirteen inches long, $2\frac{5}{8}$ inches wide and $\frac{1}{8}$ inch thick. In these cavities 17 boron carbide or

3

other material is molded under pressure and at a high temperature. In order to close the mold and press the material I provide twelve graphite plungers 18 each of which is a rectangular parallelepiped 4 inches long, 2 5/8 inches wide and 1 3/8 inch thick.

One set of graphite plungers 18 is now inserted in the mold and the assembly is then placed in a vertical position. The cavities 17 are then filled with the required amount of boron carbide or other refractory material. One satisfactory material which can be made into plates for an abrasive throwing wheel is boron carbide of the following formula:

	Per cent
B -----	77.3
C -----	21.6
Fe -----	0.03
Remainder undetermined	

While boron carbide of various particle sizes might be used, I have had good results using powder of approximately the following particle sizes:

Microns	Percentage by Weight
35-50.....	1
25-35.....	2
15-25.....	4
7-15.....	25
3-7.....	50
1-3.....	15
Finer than 1.....	3

After the mold has been charged with molding powder as above stated, the remainder of the plungers 18 are inserted in the cavities 17 opposite the first set of plungers. Each cavity 17 should have the same amount of material which is sufficient in quantity to form the final articles which, after the powder has been pressed, will be 6 3/8" long as stated. The plungers 18 at one end should project the same distance from mold 10 and the plungers 18 at the other end should project the same distance from the mold 10 and this distance should be approximately the same at one end as it is at the other. It is relatively simple to make any required adjustment in a hand press in order to achieve this result.

Now the entire assembly is placed in the graphite tube 50 of Ridgway Patent No. 2,125,588, suitable graphite spacers such as the spacers 173 of said patent are then inserted, the plungers 136 of said patent are inserted in the graphite tube 50 against the spacers, the graphite tube is heated by an electric current, pressure is applied through the plungers 136 of the above Ridgway patent and thus after a time interval six plates each 6 3/8" long by 2 5/8" by 1 3/8" are formed by sintering under heat and pressure. The sintering temperature in the case of boron carbide is just short of the fusing point of that material and for a full disclosure thereof and of the molding technique including the pressure required, reference may be had to an earlier Ridgway Patent No. 2,077,786 wherein it is stated that boron carbide has a melting point of about 2400° C. plus or minus 50° C. or probably 2375° C. as measured by optical methods. I prefer to use a pressure of 2500 pounds per square inch, for the reason that use of a standard pressure simplifies calculations and this pressure has been found to be satisfactory for all practical problems encountered. The pressure is maintained until the mold has cooled. A safe temperature at which to reduce the pressure is 500° C.

4

It remains only to remove the mold from the furnace after the furnace has cooled, to break up the graphite mold and if necessary the graphite plungers, and remove the finished pieces. They will be found to be rectangular plates of boron carbide of the dimensions previously specified, of great hardness, good uniform density within commercial limits, and have long life when used as the propelling elements in abrasive throwing wheels.

So far as certain features of the invention are concerned any refractory powder which can be sintered under heat and pressure may be used. This includes all of the refractory metals, alloys, and mixtures of metals. For example, I may make flat plates out of iron powders mixed with graphite with or without one or more of steel-forming elements such as Mn, Va, Ni, Cr and Mo in the mold and according to the method of the present invention. Also, certain refractory oxides can be molded under heat and pressure, such as beryllia, BeO. Other substances which can be pressure molded in the form of flat plates according to the invention are titanium carbide alone or mixed with iron, cobalt or nickel, titanium nitride alone or mixed with iron, cobalt or nickel, or titanium carbide or nitride with a refractory oxide such as beryl and many other compositions. Molds made according to the invention are made of carbonaceous material, preferably graphite. Graphite will reduce many oxides at sintering temperatures. However, besides beryllia, other oxides which are not easily reduced may be molded in accordance with this invention, such as Al₂O₃, ThO₂, and TiO₂. Furthermore, the invention is particularly intended for use in manufacturing sintered molded bodies out of the hard carbides including tungsten carbide, titanium carbide, vanadium carbide, and to make plates for abrasive throwing wheels as well as for other purposes, boron carbide. Boron carbide of the formula given above is substantially B₄C, but for certain purposes we may use a boron-rich carbide.

The mold of the present invention is successful for the production of long pieces for the following reasons: Graphite, which is not isotropic in strength, is actually stronger at temperatures ranging around 2270° C., than it is at room temperatures, for example, around 20° C. This is very surprising and I do not know of any other material having such characteristics. Of course, most materials have long ceased to be solid at the temperature of 2270° C. but we can measure the tensile strength of metals at a range of temperatures and without exception find that when they are red hot they are weaker than when they are cold. Understanding that no two pieces of graphite would be exactly alike, the following table is an indication of the increase of strength of graphite:

Breaking strength of graphite in pounds per square inch

	20° C.	1,500° C.	2,270° C.
Nine pieces cut.....	3,860	4,770	8,590
Parallel to Axis.....	3,864	4,730	7,590
From the Same Block.....	4,040	4,475	8,610
Six pieces cut.....	2,410	(1)	2,720
Perpendicular to Axis.....	1,860	(1)	4,360
From the Same Block.....	1,000	(1)	3,920

1 Not determined.

The second consideration is that boron carbide 75 particles do not act according to Pascal's law.

5

It is doubted if any particles act exactly according to Pascal's law but molding materials useful according to the present invention do not respond very closely to Pascal's law. This means that the pressure may be 2500 pounds per square inch where the ends of the plates are being formed, but it is a good deal less where the central portions of the plates are being formed. The next fact that makes the present invention work is that graphite is plastic at high temperatures, whereas it is brittle at low temperatures. This fact does not seem reconcilable with its apparently greater strength at high temperatures but it is a fact none the less because mistakes and accidents in molding have produced bent and twisted pieces of graphite.

The next fact that makes the present invention successful is that while graphite probably does not weld to itself very readily, it does weld to boron carbide, at least to an appreciable degree. It is now explained why attempts to make long plates of boron carbide with thick partitions in the mold were unsuccessful. The boron carbide would weld to the partition or separator plates which were so thick that despite plasticity they would not give, and differential contraction upon cooling shattered the boron carbide. The separator plates 13 and 13a are so thin that they will deform or break before the boron carbide will fracture. In the mold apparatus as described, the ratio of the thickness of the separator plates 13 and 13a to the pieces being molded is one to one. This is an important feature of the present invention and I have found that this ratio of separators to cavities should be no greater than $1\frac{1}{2}$ to 1 nor less than $\frac{3}{4}$ to 1. Within these limits good results in making long plates can be achieved but for the best practical results I now prefer a one to one ratio for boron carbide molding.

Molds according to the present invention can readily be made with a lathe, a milling machine and cutting off wheels since the various parts can be turned, milled and cut to the shapes shown. The principal reason for providing the cylindrical segments 14 and 16 is for ease of manufacture and assembly, but I could use a cylindrical mold body with a rectangular or square broached hole and grooves broached therein. In fact, the outer surface of the mold body 10 might be square or rectangular in cross section or of any other convenient or desired shape. The size of the mold body 10 is determined by the diameter of the tubes 50 in the available furnaces constructed according to the Ridgway Patent No. 2,125,588. A mold body having a diameter of $5\frac{1}{4}$ " slides easily in the tubes of the furnace without too much clearance. However the specific construction shown and described has definite advantages from the manufacturing viewpoint. This is important because each mold assembly is destroyed in order to remove the finished pieces of boron carbide or other material being molded. In other words, the mold is used only once.

The groove 11 in the outer surface of the mold body 10 is provided to accelerate the heating of the material being molded. In other words, somewhat better heat transfer is obtained by cutting away some of the graphite in the middle portion of the mold body 10 and it is found that the mold body 10 is still strong enough. In certain cases and for certain sizes of products, the cylinder

6

10 may have an unbroken outer surface or may be otherwise shaped.

The grooves 15 hold the separator plates 13 and 13a in spaced relation to form the cavities 17 thereby to facilitate loading of the mold. However it would be possible to use instruments to hold the plates one by one against the lower plungers 18 one by one during the filling operation and thus dispense with the grooves 15.

It will thus be seen that there has been provided by this invention a method and article and apparatus in which the various objects hereinabove set forth together with many thoroughly practical advantages are successfully achieved.

As various possible embodiments might be made of the mechanical features of the above invention and as the art herein described might be varied in various parts, all without departing from the scope of the invention, it is to be understood that all matters hereinbefore set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. A graphite mold assembly comprising a cylindrical outer mold body having a coaxial cylindrical bore therethrough, four cylindrical segments fitting in said bore to define a rectangular hole, there being a set of grooves in the otherwise flat surfaces of two of said segments which are placed opposite each other, the grooves in one segment being of the same size and spacing as those of the other segment, flat separator plates fitting in said grooves and extending across the rectangular hole to divide it into a number of cavities, and a set of flat plunger plates in each end of said cavities whereby the cavities may be filled with material to be pressed and sintered and then, after the cavities are closed by the plungers, the material may be molded by pressing the plungers and heating the entire mold, the ratio of the thickness of the separator plates to the plunger plates being between $1\frac{1}{2}$ to 1 and $\frac{3}{4}$ to 1.

2. Method of making flat plates of material which can be pressure-sintered which comprises providing a graphite mold with mold cavities separated by graphite plates of a thickness not greater than one and one half times the thickness of the cavities, filling the cavities and simultaneously pressing and heating the material therein, the pressure being exerted edgewise of what becomes the flat plates.

JAMES W. KNOWLTON.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
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1,589,365	Chesterfield	June 22, 1926
1,847,101	Ryschkewitsch	Mar. 1, 1932
1,953,566	Peik	Apr. 3, 1934
2,125,588	Ridgway	Aug. 2, 1938
2,169,281	Pfanstiehl	Aug. 15, 1939
2,204,633	Turnbull	June 18, 1940
2,204,635	Turnbull	June 18, 1940
2,208,536	Brown	July 16, 1940
2,301,508	Blount	Nov. 10, 1942
2,332,281	Van der Pyl	Oct. 19, 1943